

# Dense Molecular Gas at High Redshift: First Detection of Emission from HCO<sup>+</sup>

D. A. Riechers<sup>1</sup>, F. Walter<sup>1</sup>, C. L. Carilli<sup>2</sup>, A. Weiss<sup>3</sup>, F. Bertoldi<sup>4</sup>,  
K. M. Menten<sup>3</sup>, K. K. Knudsen<sup>1</sup>, and P. Cox<sup>5</sup>

<sup>1</sup>Max-Planck-Institut für Astronomie, Königstuhl 17, Heidelberg, D-69117, Germany

<sup>2</sup>National Radio Astronomy Observatory, PO Box O, Socorro, NM 87801, USA

<sup>3</sup>Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, Bonn, D-53121, Germany

<sup>4</sup>Argelander-Institut für Astronomie, Auf dem Hügel 71, Bonn, D-53121, Germany

<sup>5</sup>Institut d.RadioAstronomie Millimétrique, 300 R.d.l.Piscine, 38406 St.Martin d'Hères, France

**Abstract.** Using the Very Large Array (VLA), we have detected the HCO<sup>+</sup>(1–0) emission line towards the Cloverleaf quasar ( $z = 2.56$ ; Riechers *et al.* 2006). This is the first detection of ionized molecular gas emission at high redshift ( $z > 2$ ). HCO<sup>+</sup> emission is a star formation indicator similar to HCN, tracing dense molecular hydrogen gas within star-forming molecular clouds. We find a HCO<sup>+</sup>/CO luminosity ratio of 0.08 and a HCO<sup>+</sup>/HCN luminosity ratio of 0.8 for the Cloverleaf. These ratios fall within the scatter of the same relationships found for low- $z$  star-forming galaxies. However, a HCO<sup>+</sup>/HCN luminosity ratio close to unity would not be expected for the Cloverleaf if the recently suggested relation between this ratio and the far-infrared luminosity (Graciá-Carpio *et al.* 2006) were to hold. We conclude that a ratio between HCO<sup>+</sup> and HCN luminosity close to 1 is likely due to the fact that the emission from both lines is optically thick and thermalized and emerges from dense regions of similar volumes. We conclude that HCO<sup>+</sup> is potentially a good tracer for dense molecular gas at high redshift.

**Keywords.** galaxies: active, starburst, formation, high redshift, cosmology: observations, radio lines: galaxies

---

## Acknowledgements

D. R. acknowledges support from the Deutsche Forschungsgemeinschaft (DFG) Priority Programme 1177. C. C. acknowledges support from the Max-Planck-Gesellschaft and the Alexander von Humboldt-Stiftung through the Max-Planck-Forschungspreis.

## References

- Graciá-Carpio, J., García-Burillo, S., Planesas, P., & Colina, L. 2006, *ApJ* 640, L135  
Riechers, D. A., Walter, F., Carilli, C. L., *et al.* 2006, *ApJ* 645, L13